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A Frictional-Collisional Closure Model for the Saturated Granular Flow: Experimental Evidence and Two Phase Modelling

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Abstract : Dense granular flows widely exist in geological flows such as debris flow, landslide, or sheet flow, where both the interparticle and solid-liquid interactions are important to modify the flow. So, a two-phase approach with both phases correctly modelled is important for a better investigation of the saturated granular flows. However, a proper closure model covering a wide range of flowing states for the solid phase is still lacking. This study first employs a chute flow experiment based on the refractive index matching method, which makes it possible to obtain internal flow information such as velocity, shear rate, granular fluctuation, and volume fraction. The granular stress is obtained based on a steady assumption. The kinetic theory is found to describe the stress dependence on the flow state well. More importantly, the granular rheology is found to be frictionally dominated under weak shear and collisionally dominated under strong shear. The results presented thus provide direct experimental evidence on a possible frictional-collisional closure model for the granular phase. The data indicates that both frictional stresses exist over a wide range of the volume fraction, though traditional theory believes it vanishes below a critical volume fraction. Based on the findings, a two-phase model is used to simulate the chute flow. Both phases are modelled as continuum media, and the inter-phase interactions, such as drag force and pressure gradient force, are considered. The frictional-collisional model is used for the closure of the solid phase stress. The profiles of the kinematic properties agree well with the experiments. This model is further used to simulate immersed granular collapse, which is unsteady in nature, to study the applicability of this model, which is derived from steady flow.

Keywords : closure model, collision, friction, granular flow, two-phase model
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